working on SOFIA instruments in order to stimulate new ideas for SOFIA observational projects related to star formation.

One focus of the 1999 Ames portion of the research work of the Center involved the effect of ultraviolet radiation from young massive stars on the star-forming clouds of gas and dust that typically either surround them or lie close to them. Called "giant molecular clouds" or GMCs, these clouds typically contain 100,000 solar masses of gas and dust and are the dominant sites of star formation in galaxies. The GMCs consist primarily of cold molecular hydrogen gas found in a very clumpy structure bound together by gravity. Thousands of stars are formed in each cloud before it is dispersed in approximately ten million years by the ultraviolet radiation from the most massive stars formed in the GMC. The ultraviolet radiation photoevaporates the clumps in a GMC, destroys the molecules, and heats the gas until the thermal pressure creates a catastrophic expansion of the GMC. These processes disperse the cloud and terminate star formation, and thereby help explain why GMCs do not convert higher fractions of their mass into stars before evaporating into the diffuse interstellar medium. The heating of the gas leads to the emission of characteristic infrared spectra, which can be analyzed to determine the physical and dynamical properties of the evolving clouds.

Another focus of the Ames portion of the Center research in 1999 involved the formation and propagation of spiral density waves in the orbiting disks of gas and dust that circle a newly formed star and ultimately form planets. These spiral density waves affect the evolution of the density and angular momentum in these disks, and, therefore, the planet-forming characteristics of the disks. Analytic analysis and numerical simulations showed that two competing hypotheses explaining the cause of spiral structure in self-gravitating disks had an underlying unity. This finding provided a much better understanding of how mass and angular momentum are transported through protostellar disks. This work could also be generalized to the self-gravitating disks which characterize galaxies, and thereby resolve a long-standing debate in the galactic structure community.

The theoretical models of the Center have been used to interpret observational data from NASA facilities such as the Infrared Telescope Facility (IRTF), the infrared astronomical satellite (IRAS), the Hubble Space Telescope (HST), and the Infrared Space Observatory (ISO), a European space telescope with NASA collaboration, as well as from numerous ground-based radio and optical telescopes. In addition, they have been used to determine requirements on future missions such as SOFIA and the proposed Space Infrared Telescope Facility (SIRTF).

Point of Contact: D. Hollenbach
(650) 604-4164
hollenbach@ism.arc.nasa.gov

CCD Photometry Tests for Planet Detection

David G. Koch, William J. Borucki, Jon Jenkins, Larry D. Webster, Fred Witteborn

For the first time in history we now know of more planets outside our solar system than in it. All of these extrasolar planets are about the size of Jupiter or larger. The *Kepler Mission* proposes to search for hundreds of Earth-size planets. The concept consists of monitoring 100,000 stars continuously for four years for planetary transits. An Earth-sized transit of a solar-like star produces a relative change in brightness of 8×10^{-3} for a duration of a few to 16 hours, depending on the orbit and inclination of the planet. A technology demonstration showed that a relative precision of better than 2×10^{-5} is achievable when all of the realistic noise sources are incorporated in a full-up end-to-end system. A commercially available back-illuminated charged coupled device (CCD) was used for the tests. The same device can be used in the proposed *Kepler Mission*.

The technology demonstration test facility incorporated the ability to control and measure the following effects on the noise performance of the end-to-end system: varying the CCD operating temperature; changing the focus; varying the photometric aperture; operating over a dynamic range of five stellar magnitudes; working in a crowded star field; reading out the CCD without a shutter; translating the image to several discrete locations on the CCD; operating with a field star five magnitudes brighter than the brightest target stars; operating with spacecraft jitter up to ten times the anticipated amplitude; and simulating the effects of cosmic rays and stellar variability.

The testbed source incorporates all the characteristics of the real sky that are important to the measurements. It produces the same flux as real 9th to 14th magnitude stars, has the same spectral color as the Sun, has the same star density as the Cygnus region of the Milky Way down to stars as faint as 19th magnitude, has several 4th magnitude stars, and has the ability to produce Earth-size transits for selected stars. The camera simulates all the functions to be performed by the space-borne photometer, namely, fast optics, a flight-type CCD, readout without a shutter, a high-speed readout of one megapixel per second, and proto-flight data reduction and analysis software. Piezoelectric transducers are used to provide tip-tilt of the camera to reproduce the motion caused by spacecraft pointing jitter.

To fully demonstrate the concept, transits were created during the testing. Representative transits are shown in figure 1 for 9th (left), 12th (middle), and 14th (right) magnitude stars. The transit depth is given in equivalent Earth size, and the error bars are the one-sigma noise for the data.

Point of Contact: D. Koch
(650) 604-6548
dkoch@mail.arc.nasa.gov

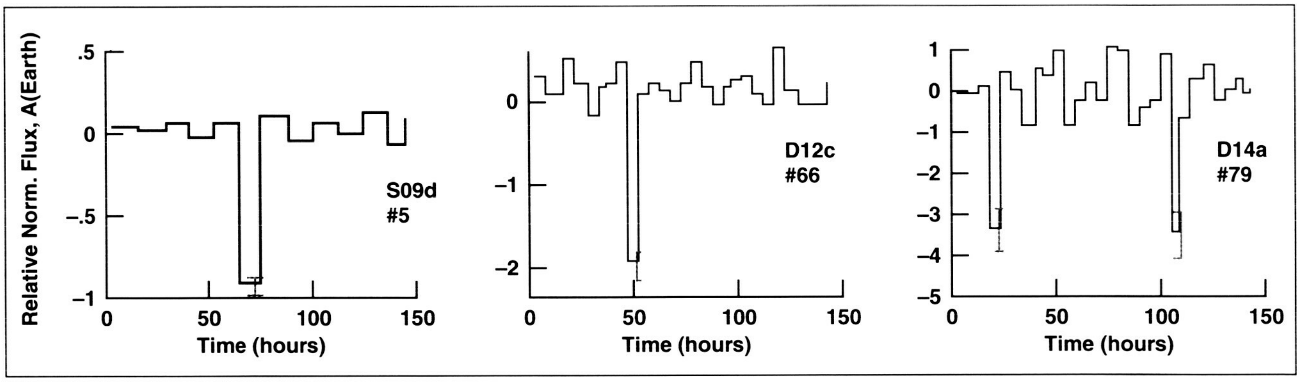

Fig. 1. Simulated transits during the running of the long-duration test with all noise sources.

Minimizing Infrared Stray Light on SOFIA

Allan W. Meyer, Sheldon M. Smith, Chris T. Koerber

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is now being designed and developed, with first light expected in late 2002. Flying at 41,000 feet or higher for 6 hours or more during 120 nights each year, SOFIA will be used for high-resolution observations of celestial objects in the infrared and submillimeter regions, spanning a factor of 1000 in wavelength. In many respects, building SOFIA is a greater challenge than an orbiting observatory would be, but advantages of economy and continuous access make it worthwhile. For work in the infrared, where everything at temperatures above absolute zero can be a source of background interference, the telescope and associated infrared sensors must be carefully designed and constructed to minimize such background. The far-infrared properties of the telescope surfaces, surrounding cavity walls, and surfaces within focal-plane instruments can be significant contributors to background noise. Infrared radiation from sources well off axis, such as the Earth, moon, or aircraft engines, may be multiply scattered by dust on the optics, the cavity walls, and/or surface facets of a complex telescope structure. This report briefly describes recent efforts at Ames Research Center to evaluate some of the infrared properties of the SOFIA telescope surfaces, and also some of the surface treatments that may be used in focal-plane infrared sensors.